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A Study of the Nonlinear Relation between Exchange Rate and Fiscal Revenue in China

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Abstract

This paper uses smooth transition regression (STR) model to study the nonlinear relation between the exchange rate of US dollar against RMB and the fiscal revenue in China. The research results show that there exists the two-way Granger causality relations between exchange rate and fiscal revenue, and exchange rate has significant nonlinear impacts to fiscal revenue.

Keyword: Exchange Rate; Fical Revenue; Nonlinear Relation; STR Model

1. Introduction

A large amount of research results show that fiscal expenditure plays an important role in economic development for almost all countries in this world. However, the amount of fiscal expenditure mainly depends on fiscal revenue. There are many influence factors of fiscal revenue. As we know that exchange rate fluctuation may directly produce influence to the import and export of a country. Such influence may lead to the increasing or decreasing of fiscal revenue. Therefore, it is obvious that exchange rate is one of such influence factors. It is of interesting to study the relation between exchange rate and fiscal revenue.

As regard to the study of influence factors for fiscal revenue, it is easily to find that there are many published papers. Some related research results were given by Andrianacos and Akarca (1998), Emran(2005), Cosgel and Miceli (2005), Kima et al. (2006), Junq and Bae(2011), Tagkalakis (2011) and

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etc. As we know that most of these results only focus on the study of relation between tax and fiscal revenue. This paper tries to use STR model to discuss the impact of exchange rate on fiscal revenue in China and hopes to find some internal phenomena.

2. Methodology

The general form of a STR model is as follows:

$$Y_t = \phi' z_t + \theta' z_t G(\gamma, c, s_t) + u_t \qquad (1)$$

where $x_t = (1, x_{1t}, \cdots, x_{pt})' = (1, y_{t-1}, \cdots, y_{t-k}, z_{1t}, \cdots, z_{mt})$ is a vector of exogenous variables, $t = 1, \cdots, T$, $p = k + m$; both $\phi = (\phi_0, \phi_1, \cdots, \phi_m)'$ and $\theta = (\theta_0, \theta_1, \cdots, \theta_m)'$ are parameter vectors; $u_t \sim N(0, \sigma^2)$; transition function $G(\gamma, c, s_t)$ is a bounded transition function of s_t; c is the threshold value.

If $G(\gamma, c, s_t) = 1 - \exp(-\gamma(s_t - c)^2)$ then the model (1) is called an exponential STR (ESTR) model. The model (1) is called a logistic STRK (LSTRK) model if $G(\gamma, c, s_t) = (1 + \exp\{-\gamma \prod_{k=1}^{K} (s_t - c_k)\})^{-1}$. Particularly, models LSTR1 and LSTR2 are corresponding to the cases $K = 1$ and $K = 2$ respectively.

The STR modeling process consists of the following four steps: (a) Estimate the linear part in the model by regression method and fix the lagging order of the auto-regression based on AIC and SC; (b) Test the existence of nonlinearity with LM statistic and choose the optimal form of STR model and transition variables through sequential test; (c) Estimate the parameter vectors by Newton-Raphson method; (d) Evaluate the goodness-of-fitting of the model.

3. Empirical Analysis

In this paper, we will investigate the relationship between exchange rate (ER) of US dollar against RMB and the fiscal revenue index (Re) in China from January, 1994 to November 2009; both variables are monthly data collected from China Economic Information Network (http://db.cei.gov.cn/). Let Δer and $\Delta \mathrm{Re}$ be the one order differences of er and Re respectively, $\ln \Delta er$ and $\ln \Delta \mathrm{Re}$ be the corresponding logarithm forms, $\ln \Delta er(-t)$ and $\ln \Delta \mathrm{Re}(-t)$ be their corresponding t-period lagging-values.

3.1. Stationary Test of the Data and Granger Causality Test

In order to use STR model to study the relationship between exchange rate and fiscal revenue, we need to require that both variables are stationary and there exists Granger causality relation between them. By using Augmented Dickey Fuller test (ADF) test, we can easily find both variables $\ln \Delta er$ and $\ln \Delta \mathrm{Re}$ are stationary under different significant levels (1%, 5% and 10%) while exchange rate and fiscal revenue are not stationary. The p-values of two ways of Granger causality test are 0.04887 and 0.02383 respectively, this result shows that there exist two ways of Granger causality between $\ln \Delta er$ and $\ln \Delta \mathrm{Re}$. In the following study, we will only investigate the impact of $\ln \Delta er$ on $\ln \Delta \mathrm{Re}$.

3.2. Estimation

In this section, we employ the STR model to explore the internal relation between $\ln \Delta \mathrm{rate}$ and $\ln \Delta \mathrm{Re}$ based on the above mentioned steps.

By using regression method and AIC, we can find the optimal lagging order of the linear part in the model (1) is 16. The obtained result of linear part is as follows:

$$\begin{aligned} ln\Delta Re = & -0.588\, ln\Delta Re(-1) - 0.567\, ln\Delta Re(-2) - 0.266\, ln\Delta Re(-3) - 0.342\, ln\Delta Re(-4) \\ & -0.544\, ln\Delta Re(-5) - 0.477\, ln\Delta Re(-6) - 0.478\, ln\Delta Re(-7) - 0.501\, ln\Delta Re(-8) \\ & -0.431\, ln\Delta Re(-9) - 0.496\, ln\Delta Re(-10) - 0.506\, ln\Delta Re(-11) + 0.249\, ln\Delta Re(-12) \\ & -0.206\, ln\Delta Re(-15) - 0.168\, ln\Delta Re(-16) - 4.714\, ln\Delta er + 0.089 + \varepsilon \end{aligned} \quad (2)$$

After testing the nonlinear relation between the variables with F statistics, the transition variable and nonlinear model form can be decided through the sequential test. The detailed results are given in Table 1 and show that LSTR1 with the $\ln\Delta \mathrm{Re}(-9)$ as the transition variable is the best choice by comparing the P-values.

Table 1. The results of nonlinearity test

s_t	F	F4	F3	F2	Model Form
$\ln\Delta \mathrm{Re}(-1)$	1.2970e-02	7.1704e-02	3.8916e-03	8.0667e-01	ESTR
$\ln\Delta \mathrm{Re}(-2)$	5.4696e-01	5.2491e-01	8.5011e-01	1.5433e-01	Linear
$\ln\Delta \mathrm{Re}(-3)$	4.6809e-03	9.1619e-02	5.1698e-02	3.2110e-02	LSTR1
$\ln\Delta \mathrm{Re}(-4)$	3.7357e-02	7.2290e-02	3.3257e-01	8.8851e-02	LSTR1
$\ln\Delta \mathrm{Re}(-5)$	1.6992e-02	3.2162e-01	9.6432e-02	1.2687e-02	LSTR1
$\ln\Delta \mathrm{Re}(-6)$	3.2001e-04	4.3888e-03	1.2960e-01	1.2027e-02	LSTR1
$\ln\Delta \mathrm{Re}(-7)$	1.4875e-01	3.0232e-01	6.4422e-01	3.5293e-02	Linear
$\ln\Delta \mathrm{Re}(-8)$	1.4528e-01	5.1678e-01	3.8101e-01	3.2684e-02	Linear
$\ln\Delta \mathrm{Re}(-9)$ *	1.7417e-06	4.0297e-04	1.3933e-01	1.6295e-04	LSTR1 *
$\ln\Delta \mathrm{Re}(-12)$	1.2757e-05	1.9176e-02	9.9708e-04	7.7668e-03	ESTR
$\ln\Delta \mathrm{Re}(-15)$	3.2313e-03	4.0239e-01	1.0952e-01	3.0662e-04	LSTR1
$\ln\Delta \mathrm{Re}(-16)$	5.7554e-01	9.4573e-01	1.8311e-01	3.2820e-01	Linear
$\ln\Delta er$	NaN	NaN	NaN	2.3328e-02	Linear

3.3. Model parameter estimation and analysis

Firstly, we can use grid search method to choose the estimate of (γ, c) which minimize the corresponding SSR. Secondly, the Newton-Raphson method is employed to estimate the parameters in the model and the final fitted model can be obtained by deleting non-significant variables. The corresponding results are listed in Table 2.

Table 2. The estimation results of LSTR1

	Variables	Initial value	Estimate	T-value
Linear part	constant	0.13033	0.14193	2.7018***
	$\ln\Delta er$	-5.28283	-6.58936	-1.6727*
	$\ln\Delta \mathrm{Re}(-1)$	-0.65742	-0.74929	-5.8224***
	$\ln\Delta \mathrm{Re}(-2)$	-0.71386	-0.83407	-4.6774***
	$\ln\Delta \mathrm{Re}(-3)$	-0.44338	-0.54831	-3.1903***
	$\ln\Delta \mathrm{Re}(-4)$	-0.48788	-0.52182	-3.3165***

	$\ln\Delta Re(-5)$	-0.62905	-0.74469	-4.8390***
	$\ln\Delta Re(-6)$	-0.31380	-0.39006	-2.6994***
	$\ln\Delta Re(-7)$	-0.56569	-0.70838	-4.2745***
	$\ln\Delta Re(-8)$	-0.58430	-0.66556	-4.4347***
	$\ln\Delta Re(-9)$	-0.50645	-0.63754	-2.8411***
	$\ln\Delta Re(-10)$	-0.81822	-0.90493	-4.9256***
	$\ln\Delta Re(-11)$	-0.90496	-1.01384	-5.3173***
	$\ln\Delta Re(-12))$	-0.33150	-0.43660	-1.8757*
	$\ln\Delta Re(-15)$	-0.13197	-0.12573	-1.4289
	$\ln\Delta Re(-16)$	-0.16826	-0.19815	-2.1101**
Nonlinear part	constant	-0.18901	-0.21770	-1.2128
	$\ln\Delta er$	12.88718	16.68561	1.8620*
	$\ln\Delta Re(-1)$	0.65742	0.74929	5.8224***
	$\ln\Delta Re(-2)$	0.61263	0.79622	2.6444***
	$\ln\Delta Re(-3)$	0.79186	1.04999	2.6979***
	$\ln\Delta Re(-4)$	0.83150	0.93595	2.4221**
	$\ln\Delta Re(-5)$	0.83383	1.15923	3.2798***
	$\ln\Delta Re(-6)$	0.60218	0.63779	1.8722*
	$\ln\Delta Re(-7)$	0.96906	1.39715	3.2505***
	$\ln\Delta Re(-8)$	0.83480	1.05063	2.7372***
	$\ln\Delta Re(-9)$	0.86143	1.26192	3.0378***
	$\ln\Delta Re(-10)$	1.11727	1.48405	3.6416***
	$\ln\Delta Re(-11)$	1.26718	1.68571	4.3482***
	$\ln\Delta Re(-12)$	1.61234	2.04277	4.6097***
	$\ln\Delta Re(-13)$	0.19298	0.26692	1.1349
	$\ln\Delta Re(-14)$	0.50904	0.61294	2.6613***
	$\ln\Delta Re(-15)$	0.13197	0.12573	1.4289
	$\ln\Delta Re(-16)$	0.16826	0.19815	2.1101**
	γ	4.85242	1.68834	2.3688**
	c	0.08367	0.14829	1.8225*
Model fitting evaluation	-4.8906 (AIC)，-4.2915 (SC), -4.6476 (HQ)，0.91678 ($\bar{R}^2$), 0.9173 (R^2)			

Here *, ** and *** stand for significant levels 1%, 5% and 10%

According to the results in Table 2, we can get the final fitted STR model as equation (3).

In addition, we can obtain the following explanations:

The parameter γ =1.68834 shows that the speed of transition from linear model to nonlinear model is slow and c=0.14829 means that the critical value of transition for s_t is small. By selecting $\ln\Delta Re(-9)$ as s_t, the model (3) implies that the fiscal revenue of last nine month has a significant impact on current fiscal revenue in China, which also means the lagged time is long for the influence of exchange rate to fiscal revenue. This is mainly due to the time of both collections of the fiscal revenue and exchange rate policies effect is a long process.

$$\begin{aligned}\ln \Delta \mathrm{Re} = {} & 0.142 - 6.589 \ln \Delta er - 0.749 \ln \Delta \mathrm{Re}(-1) - 0.834 \ln \Delta \mathrm{Re}(-2) - 0.548 \ln \Delta \mathrm{Re}(-3) \\ & -0.522 \ln \Delta \mathrm{Re}(-4) - 0.745 \ln \Delta \mathrm{Re}(-5) - 0.390 \ln \Delta \mathrm{Re}(-6) - 0.708 \ln \Delta \mathrm{Re}(-7) \\ & -0.666 \ln \mathrm{Re}\,\Delta(-8) - 0.638 \ln \mathrm{Re}\,\Delta(-9) - 0.905 \ln \mathrm{Re}\,\Delta(-10) - 1.014 \ln \mathrm{Re}\,\Delta(-11) \\ & -0.437 \ln \Delta \mathrm{Re}(-12) - 0.126 \ln \Delta \mathrm{Re}(-15) - 0.198 \ln \Delta \mathrm{Re}(-16) + G(\gamma, c, s_t) \\ & \{-0.218 + 16.686 \ln \Delta er + 0.749 \ln \Delta \mathrm{Re}(-1) + 0.796 \ln \Delta \mathrm{Re}(-2) + 1.050 \ln \Delta \mathrm{Re}(-3) \\ & +0.936 \ln \Delta \mathrm{Re}(-4) + 1.159 \ln \Delta \mathrm{Re}(-5) + 0.638 \ln \Delta \mathrm{Re}(-6) + 1.397 \ln \Delta \mathrm{Re}(-7) + \\ & 1.051 \ln \mathrm{Re}\,\Delta(-8) + 1.262 \ln \mathrm{Re}\,\Delta(-9) + 1.484 \ln \mathrm{Re}\,\Delta(-10) + 1.686 \ln \mathrm{Re}\,\Delta(-11) \\ & 2.043 \ln \mathrm{Re}\,\Delta(-12) + 0.267 \ln \mathrm{Re}\,\Delta(-13) + 0.613 \ln \mathrm{Re}\,\Delta(-14) + 0.126 \ln \mathrm{Re}\,\Delta(-15) \\ & 0.198 \ln \Delta \mathrm{Re}(-16)\}\end{aligned} \tag{3}$$

When $\ln \Delta \mathrm{Re}(-9)$ is less than 0.14829, we have $G(\gamma, c, s_t) = 0$ and the model displays linear characteristics. According to the result in the model (3), we know that one unit increases in exchange rate will result in 6.5% unit decrease in current fiscal revenue in China. We guess that such a situation lies mainly in that our international trade can't meet Marshall- Lena condition at this time, which means that the devaluation of RMB cannot improve the payment balance.

When $\ln \Delta \mathrm{Re}(-9)$ is more than 0.14829, we have $G(\gamma, c, s_t) > 0$ and the model displays nonlinear characteristics. In this case, the fiscal revenue will be added with the increasing of exchange rate. The devaluation of RMB improves the payment balance in the international trade, promotes the economic development, and results in the increasing of the fiscal revenue. As the fiscal revenue is big enough than 0.0837 billion from 1994 in China, the nonlinear part in the model (3) reflects the current situation better.

4. Discussion and Conclusion

By using Granger causality test, we find that there exist two ways Granger causality relations between exchange rate of US dollar against RMB and fiscal revenue. Furthermore, we employ nonlinear time series STR model to investigate the impact of exchange rate on fiscal revenue. The fitted model shows that such impact indeed exists and nonlinear relation had been existed from 1994 to 2009. In addition, whether there is the linear (nonlinear) impact of exchange rate on fiscal revenue is decided by $\ln \Delta \mathrm{Re}(-9)$ is less than (bigger than) 0.14829. Chinese government may take suitable measures to increase fiscal revenue according to the findings in this paper.

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